

## DESCRIPTION

### ELECTROSTATIC CHUCK AND ITS MANUFACTURING METHOD

#### Field of the Invention

The present invention relates to an electrostatic chuck for use in an etching apparatus for manufacturing semiconductors and its manufacturing method.

#### Background Art

In a semiconductor manufacturing process, etching processes are repeatedly performed together with insulating film formation, diffusion processes and photolithographic processes. There are two types of etching process; wet etching and dry etching. The dry etching is implemented using a plasma etching apparatus as shown in Fig. 4, for example, with a semiconductor wafer W held on a chuck 12 in a processing chamber 11 of the etching apparatus, a reactive gas is introduced from an inlet 13 into the above-described chamber 11 while high-frequency electric power 15 is applied between the chuck 12 which serves as a lower electrode and an upper electrode 14 so as to generate a plasma in the processing chamber 11, by which chemical reaction with radical in the plasma and accelerated ions etch the semiconductor wafer W, more particularly the semiconductor wafer W itself or an insulating film (not shown) thereon.

In this dry etching, the semiconductor wafer W is held on chuck 12 as described above. Recently, for the chuck 12,

an electrostatic chuck is specified due to its excellent characteristics proved in vacuum plasma processors.

The electrostatic chuck attracts material to be attracted by generating electrostatic attraction between the material to be attracted and the chuck. The electrostatic attraction is made of two types of forces; Coulomb force and Johnsen-Rahbek force.

There are two types of the electrostatic chuck; one is a unipolar type in which only an anode 22 is formed in dielectric material 21 and a cathode is made of the apparatus and a plasma electric potential as shown in Fig. 5, and the other is a bipolar type in which both an anode 32 and a cathode 33 are formed in dielectric material 31 as shown in Fig. 6.

Referring to Fig. 7, there is shown a cross-sectional view illustrating an example of a conventional practically-used electrostatic chuck. This electrostatic chuck comprises an anodized aluminum film 42 which is 50 to 60  $\mu\text{m}$  in thickness as dielectric material on a surface of a disc-shaped aluminum electrode 41. The anodized aluminum film 42 is the material on which the semiconductor wafer W is placed. On a surface of the aluminum electrode 41 covered by the anodized aluminum film 42, is formed a cooling gas channel 43 extending in a circumferential direction of the electrode. To this cooling gas channel 43, a helium gas is fed as cooling gas from gas feed orifices (not shown) penetrating the anodized aluminum film 42 and the aluminum electrode 41.

In the conventional electrostatic chuck as set forth in the above, however, there is a disadvantage that reaction products which have been floating or otherwise dispensed in the chamber 11 shown in Fig. 4 adhere to a surface of the anodized aluminum film 42, after the semiconductor wafer W is removed from the chuck after the etching process, thus weakening the electrostatic attraction. In addition, it has a problem that the reaction products adhering to the surface of the anodized aluminum film 42 increases gaps between the anodized aluminum film 42 and the semiconductor wafer W, causing leakage of the helium gas from an outer peripheral edge of the aluminum electrode 41, by which the semiconductor wafer W is insufficiently cooled by the helium gas and therefore the etching characteristics deteriorate. Furthermore, the anodized aluminum film 42 is deteriorated

by the reactive gas or ions which have passed through end portions of the semiconductor wafer W during etching before reaching there, thus also weakening the electrostatic attraction.

Accordingly, there has been devised an electrostatic chuck for which a ceramic layer is used for the dielectric material as shown in Fig. 8. This electrostatic chuck has a ceramic layer 53 bonded onto a disc-shaped metal base plate 51 by means of an adhesive layer 52. A high-melting point electrode 54 is laid in the ceramic layer 53. In this arrangement, from the viewpoint of increasing the electrostatic attraction, the electrode 54 is located in the ceramic layer 53 relatively near the surface thereof. Specifically, on the assumption that the ceramic layer 53 is 1 mm in thickness, for example, the electrode 54 is located in a position spaced 0.3 mm away from the surface of the ceramic layer 53 and spaced 0.7 mm away from the bottom thereof. In the same manner as for the electrostatic chuck shown in Fig. 7, is formed a cooling gas channel 55 extending in a circumferential direction of the ceramic layer 53 on the surface thereof. This channel 55 needs a certain depth taking into consideration a flow of the helium gas. Therefore, if the above-described channel 55 is formed in the position of the electrode 54 located relatively near the surface of the ceramic layer 53, a distance between the bottom of the channel 55 and the electrode 54 becomes short, thus causing an insufficient dielectric strength of the

ceramic layer 53. Accordingly, in this example, the channel 55 is formed 1 to 2 mm within the end of the ceramic layer 53, and the electrode 54 is formed further within the channel 55.

The above-described electrostatic chuck has a problem, however; the electrode 54 having a coefficient of linear thermal expansion different from that of the ceramic layer 53 is located in the ceramic layer 53 relatively near the surface thereof, which often causes a warpage of the ceramic layer 53 if the ceramic layer 53 within the electrode 54 is formed by firing. In addition, while a leakage of the helium gas fed to the channel 55 from the end portion of the ceramic layer 53 is prevented by the sealed portion between the ceramic layer 53 and the semiconductor wafer W between the channel 55 and the end portion of the ceramic layer 53, such a short distance of the sealed portion (a sealed distance) as 1 to 2 mm sometimes causes a gas leakage.

In order to prevent the gas leakage, there is also another example that the channel 55 is formed approximately 3 to 10 mm within the end of the ceramic layer 53 as shown in Fig. 9, so as to achieve a substantial sealed distance. This example also has a problem, however; the electrode 54 is formed further within the channel 55 located within the end of the ceramic layer 53, which effectively decreases an area of the electrode 54, thus causing insufficient electrostatic attraction in the helium gas sealed portion.

Furthermore, there are many examples of conventional

electrostatic chucks in which a wafer W attracted to a chuck cannot always be readily detached, or "dechucked" therefrom after a completion of etching or other processes. In some cases, it takes a considerable time for detachment of the wafer w.

The present invention overcomes problems associated with prior art arrangements, and provides an electrostatic chuck and its manufacturing method for preventing warpage of a ceramic layer and a cooling gas leakage in addition to having enhanced electrostatic attraction and requiring only a short time for detachment.

#### Summary Disclosure of the Invention

The present invention provides an electrostatic chuck in which a disc-shaped ceramic layer having a predetermined thickness is bonded to a metal base plate by means of an adhesive layer, a planar electrode is located in the ceramic layer in the middle thereof in the thickness direction, a cooling gas channel is formed on a surface of the ceramic layer within the outer edge of the electrode and over the electrode, and the electrode extends beyond the cooling gas channel.

An alternative aspect of the invention provides a method of manufacturing an electrostatic chuck comprising the steps of preparing a first disc-shaped ceramic material compact having a thickness which is approximately one-half of a completed ceramic layer, forming an electrode on a

surface of the first ceramic material compact, preparing a second disc-shaped ceramic material compact having a thickness which is approximately one-half of the completed ceramic layer and including a cooling gas channel on its surface within the electrode, placing the second ceramic material compact on the first ceramic material compact to form a laminate and then firing the entire laminate so as to complete the ceramic layer, and bonding the completed ceramic layer onto a metal base plate by means of an adhesive layer.

#### Brief Description of the Drawings

Fig. 1 is a cross-sectional view of an embodiment of an electrostatic chuck according to the present invention;

Fig. 2 is a top plan view of an electrode of the electrostatic chuck illustrated in Fig. 1;

Fig. 3 is a top plan view of a ceramic layer of the electrostatic chuck illustrated in Fig. 1;

Fig. 4 is a schematic view illustrating a dry etching apparatus;

Fig. 5 is a schematic view illustrating a unipolar-type electrostatic chuck;

Fig. 6 is a schematic view illustrating a bipolar-type electrostatic chuck;

Fig. 7 is a cross-sectional view illustrating a conventional first electrostatic chuck;

Fig. 8 is a cross-sectional view illustrating a

conventional second electrostatic chuck; and

Fig. 9 is a cross-sectional view illustrating a conventional third electrostatic chuck;

#### Detailed Description of the Invention

A description will be given of an electrostatic chuck and its manufacturing method according to the present invention, by referring to the accompanying drawings. The electrostatic chuck of the present invention is used for a dry etching apparatus. A general configuration of the dry etching apparatus is shown in Fig. 4. Accordingly, a description of the general configuration of the dry etching apparatus is omitted here, and only the electrostatic chuck is described in detail below.

Referring to Fig. 1, there is shown a cross-sectional view of an electrostatic chuck of an embodiment according to the present invention. As shown in this diagram, in the electrostatic chuck of this embodiment, a disc-shaped ceramic layer 80 having a predetermined thickness is bonded onto a disc-shaped metal base plate 60 by means of an adhesive layer 70. In this ceramic layer 80, a planar electrode 90 made of tungsten, for example, is laid in parallel to a surface of the ceramic layer 80. At this point, the electrode 90 is formed in the ceramic layer 80 at a depth of one half of the thickness thereof, in other words, in the middle of the ceramic layer 80 in the thickness direction.



A top plan view of this electrode 90 is shown in Fig. 2. The electrode 90 comprises a first electrode 91 and a second electrode 92. Therefore, the electrostatic chuck of this embodiment is of a bipolar type as shown in Fig. 6. The first electrode 91 comprises a disc portion 91a arranged in the center of the ceramic layer 80, a linear portion 91b linearly extending from a part of the disc portion 91a toward an outer peripheral edge of the ceramic layer 80. The first electrode 91 further comprises a plurality of "C-shaped" ring portions 91c at predetermined intervals having different diameters and extending in "C" shapes on both sides of the linear portion 91b so as to surround the disc portion 91a. The second electrode 92 comprises a linear portion 92b positioned opposite to the linear portion 91b of the first electrode 91 beyond the disc portion 91a of the first electrode 91 and arranged complementary to the plurality of the C-shaped ring portions 91c of the first electrode 91, a plurality of "C-shaped" ring portions 92c at predetermined intervals having different diameters and extending in "C" shapes on both sides of the linear portion 92b, and, being engaged with the plurality of the C-shaped ring portions 91c of the first electrode 91. Furthermore, the electrode 91 comprises a circular ring portion 92d connected to an outer edge of the linear portion 92b so as to form the outermost peripheral portion of the electrode.

Returning to Fig. 1, a cooling gas channel 81 is formed on a surface of the ceramic layer 80. The cooling gas

channel 81 is provided in a ring shape along the outer peripheral edge of the ceramic layer 80 as shown in a top plan view in Fig. 3. In addition, the channel 81 is formed within the outer peripheral edge of the electrode 90 and over the electrode 90 as shown in Fig. 1. Accordingly, the electrode 90 passes under the bottom of the channel 81 and extends beyond the channel 81 and up to the vicinity of the outer peripheral side of the ceramic layer 80.

At a bottom of the channel 81, there are gas feed orifices 82 in a plurality of positions in a circumferential direction as shown in Fig. 3. Additionally on a surface of the ceramic layer 80 in the center side, gas feed orifices 83 are arranged in a plurality of positions on a single circumference. These gas feed orifices 82 and 83 extend through the ceramic layer 80, the adhesive layer 70, and the base plate 60 up to the bottom thereof. A cooling gas such as a helium gas, for example, is fed from the bottom of the base plate 60. The helium gas fed to the gas feed orifices 82 and 83 spouts from the bottom of the channel 81 and from the surface of the ceramic layer 80 in the center and diffuses from the outer peripheral portion of the ceramic layer 80 and from the center thereof on the entire interface between the ceramic layer 80 and the semiconductor wafer W, as shown in Fig. 1, so as to cool the semiconductor wafer W.

According to the electrostatic chuck of this embodiment as described above, the electrode 90 comprising a high-melting point metal having a coefficient of linear

thermal expansion different from that of the ceramic layer 80 is disposed/located in the ceramic layer 80 in the middle thereof in its thickness direction. Therefore, even if the ceramic layer 80 is formed in the electrode 90 with firing, the ceramic layer 80 is not warped so as to obtain a flat ceramic layer 80. In addition, improvement of the flatness of the ceramic layer 80 leads to improvement of etching characteristics (for example, uniformity) of the semiconductor wafer W as well as increasing the attraction of the semiconductor wafer W.

Furthermore, the cooling gas channel 81 is formed within the outer peripheral edge of the electrode 90 and over the electrode 90. Thus, the electrode 90 extends beyond the channel 81, in other words, up to the gas-sealed portion. Therefore, electrostatic attraction is also applied to the sealed portion by means of the electrode 90 as indicated by arrows, thus preventing a gas leakage from the sealed portion with the electrostatic attraction. The prevention of the gas leakage leads to improved cooling condition of the semiconductor wafer W, improving the etching characteristics, such as uniformity center-to-edge as measured on the wafer.

Furthermore, by positioning the electrode 90 in the middle (in a deep position) of the ceramic layer 80 in its thickness direction, the channel 81 can be formed sufficiently deep even if it is located over the electrode 90, by which the helium gas smoothly flows so as to cool the semiconductor wafer W favorably. In addition, by forming the

channel 81 over the electrode 90, a long distance of the sealed portion can be secured by disposing the channel 81 within the ceramic layer 80, by which a gas leakage can be prevented more reliably and an area of the electrode does not need to be decreased due to a position of the channel 81. Also, even if the electrode 90 is located in a deep position in the ceramic layer 80, sufficient electrostatic attraction can be secured since electrostatic attraction is also applied to the sealed portion as described in the above.

Furthermore, by using a pattern shown in Fig. 2 for the first and second electrodes 91 and 92 of the electrode 90, the first and second electrodes 91 and 92 having an identical area can be uniformly formed all over the ceramic layer 80, by which uniform electrostatic attraction can be achieved on the entire ceramic layer 80. Still further, the ratio of the area of the electrode 91 to the area of the ceramic layer 80 can be increased, by which the electrostatic attraction is enhanced. Additionally, with the ESC of the present invention, detaching or "dechucking" performance of a wafer after processing is improved in comparison with an ESC made with conventional doughnut or threading pattern, where the conventional pattern causes an uneven ratio of an area of the first electrode to that of the second electrode, thus leading to a maldistribution of electric charges and causing poor dechucking performance.

#### Embodiment

The base plate 60 is preferably formed by using an

aluminum 6061, for example. A high radio frequency(RF) power is fed to this base plate 60 in order to generate a plasma in a chamber 11 of an apparatus shown in Fig. 4. The high radio frequency power to be applied may be in the range of 1 to 40 MHz in frequency and of 15 to 3000 W in power.

For the adhesive layer 70, a suitable, flexible, preferably organic, adhesive is used. With the ceramic layer 80 bonded to the base plate 60 by means of the flexible organic adhesive, the ceramic layer 80 is prevented from cracking caused by differential stress due to a difference of a coefficient of linear thermal expansion.

The ceramic layer 80 is formed by adding conductive additive to aluminum oxide, for example, aluminum nitride, or magnesium oxide. In this embodiment, it is formed by using a material of  $\text{Al}_2\text{O}_3$  as a predominant component, and  $\text{TiO}_2$  and glass firing auxiliary material as additives. The additive  $\text{TiO}_2$  is added to cause the ceramic layer 80 to be slightly conductive so as to let electric charges for generating electrostatic attraction rise from the electrode 90 up to the surface of the ceramic layer 80. A resistivity of the ceramic layer 80 is selected so that it is within a range of  $10^{11}$ - $10^{12}$   $\Omega/\text{cm}$ , and preferably within a range of 1.0 to  $2.0 \times 10^{11}$   $\Omega/\text{cm}$ .

A diameter of the ceramic layer 80 is slightly smaller than that of the semiconductor wafer W, and a thickness of the ceramic layer 80 is approximately 1 mm taking into consideration dielectric breakdown and an energy loss of the

high-frequency power. Surface roughness of the ceramic layer 80 is  $Ra \approx 0.8 \mu m$  and flatness thereof is  $5 \mu m$  or lower. The outer peripheral edge on the surface of the ceramic layer 80 is chamfered by 0.2 to 0.25 mm.

The cooling gas channel 81 is formed so as to extend 5 mm within the outer peripheral edge of the ceramic layer 80 and to be 1 mm wide and 0.25 mm deep. On the bottom surface of the cooling gas channel 81, eight gas feed orifices 82 are formed at  $45^\circ$  intervals in a circumferential direction. On the surface of the ceramic layer 80 in the center side, four gas feed orifices 83 are formed at  $90^\circ$  intervals on the circumference of 0.35 mm diameter. Each gas feed orifice 82 on the bottom surface of the cooling gas channel 81 is 0.32 mm in diameter and each gas feed orifice 83 on the surface of the ceramic layer 80 in the center side is 0.35 mm in diameter. The gas feed orifices 83 on the surface of the ceramic layer 80 in the center side serve as insertion orifices of pins for lifting the semiconductor wafer W, and therefore they are formed so as to be slightly larger than the gas feed orifices 82 on the bottom surface of the channel 81.

The electrode 90 (consisting of the first and second electrodes 91 and 92) is made of tungsten which is 10-20  $\mu m$  in thickness. This electrode 90 is approximately 1 mm smaller than the ceramic layer 80 in radius and it is laid in a position spaced 0.5 mm away from the surface and 0.5 mm away from the bottom of the ceramic layer 80 having a

thickness of 1 mm. In other words, the electrode 90 is positioned in the middle of the ceramic layer 80 in a thickness direction.

The disc portion 91a of the first electrode 91 shown in Fig. 2 is approximately 30 mm in diameter. The linear portion 91b of the first electrode 91 and the linear portion 92b of the second electrode 92 are approximately 6.0 mm wide. There are seven C-shaped ring portions 91c of the first electrode 91 having consecutively increasing diameters and seven C-shaped ring portions 92c of the second electrode 92 having consecutively increasing diameters. A single circular ring portion 92d of the second electrode 92 is provided on the outermost periphery. The C-shaped ring portions 91c of the first electrode 91, the C-shaped ring portions 92c of the second electrode 92, and the circular ring portion 92d have widths slightly different each other, and their average width is approximately 5.0 mm. Respective portions of the first electrode 91 are spaced 1.0 mm away from respective corresponding portions of the second electrode 92. The total area of the first electrode 91 is  $128.3 \text{ cm}^2$  and that of the second electrode 92 is nearly the same size,  $128.4 \text{ cm}^2$ .

#### <Manufacturing method>

Preparing a first disc-shaped ceramic material compact having a half of a thickness of a ceramic layer 80, an electrode is formed on a surface of the first ceramic material compact in a screen process printing method. Preparing a second disc-shaped ceramic material compact

having a half of the thickness of the ceramic layer 80 and including a cooling gas channel on its surface within the electrode, the second ceramic material compact is placed on the above-described first ceramic material compact for contact bonding. Afterward, the entire material is fired to complete the ceramic layer 80. In this process, no warpage occurs since the electrode is located in the middle of the ceramic layer 80 in a thickness direction. Subsequently the ceramic layer 80 is bonded to an aluminum base plate 60 by means of an adhesive layer 70.

<Other applications>

While the invention has been described above by way of an example of an electrostatic chuck according to the present invention applied to a dry etching apparatus, the electrostatic chuck of the present invention may be also be implemented within a CVD apparatus or the like, for example a target. In addition, it can be adapted for use in a chuck for electrostatically attracting material other than semiconductor wafers, for example, ceramic substrates.

#### Industrial Applicability

As described in detail hereinabove, according to an electrostatic chuck of the present invention and its manufacturing method, warpage of a ceramic layer is prevented. Furthermore, it prevents a cooling gas leakage at the periphery and increases an electrostatic attraction.